Lake Clark Sockeye Salmon Escapement and Population Monitoring

Annual Report for Study FIS 08-405


Photo Credit: Reilly Newman

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December 2009

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ABSTRACT

Sockeye salmon originating from the Kvichak River watershed have historically dominated valuable subsistence, sport, and commercial fisheries in Bristol Bay, Alaska. Obtaining reliable estimates of spawning escapement over time from important subsistence stocks is the number one priority identified by the Subsistence Fisheries Resource Monitoring Program for Bristol Bay. The Lake Clark sockeye salmon escapement, an important component of the Kvichak return, has been estimated intermittently since 1980 with annual estimates made since 2000. This report describes findings for the 2008 field season at the Newhalen River counting tower. Specific objectives were to 1) estimate sockeye salmon escapement to Lake Clark and 2) determine the age and size composition of the Lake Clark escapement. Estimates of sockeye salmon escapement were made at river kilometer 36 on the Newhalen River using the same tower site and protocols that were used in previous years. Sockeye salmon age and size were determined from otoliths collected from the Sixmile Lake subsistence fishery and from post-spawning fish at Lake Clark spawning areas. In 2008, the estimated Lake Clark escapement was 472,972 sockeye salmon, which comprised 17% of the total Kvichak River escapement. This escapement was 20% less than the mean escapement from 2004 – 2007, but 219% greater than the mean escapement from 2000 – 2003. Run timing was similar to previous years although total run duration was 9 days longer than the historic median. The age composition of the Lake Clark escapement, as determined from spawning area samples, was predominately age 1.3 (65%) followed by age 1.2 (34%), age 2.2 (1%), and age 2.3 (<1%) fish.

INTRODUCTION

The world's largest, most valuable sockeye salmon fisheries occur in Bristol Bay, Alaska, and fish originating in the Kvichak River watershed (Figure 1) have historically dominated regional harvests (Forrester 1987, Dye et al. 2006, Fall et al. 2007, Ruggerone and Link 2006, Sands et al. 2008). During peak years in the 1960s and 1970s the Kvichak produced 23-42 million salmon per year and represented up to 80% of Bristol Bay sockeye salmon production (Ruggerone and Link 2006). Subsistence harvests of sockeye salmon in the Kvichak River watershed have historically been the largest within the Bristol Bay region and averaged 57,379 fish during 1987 – 2007 and 49,901 fish in 2007 (Sands et al. 2008). During 2001 – 2005 the average sport fish harvest of sockeye salmon in the watershed was 1,225 fish, making it one of the largest recreational fisheries in the region (Dye et al. 2006).

Since 1996, unpredicted declines in sockeye salmon returns to the Kvichak River and Lake Clark watersheds impacted regional commercial, subsistence, and sport fisheries. During 1996 – 2003 the average Kvichak River escapement declined 64% from 5.7 million fish during 1955 – 1995 (range = 0.2 to 24.3 million) to 2.1 million salmon (range = 0.7 to 6.2 million fish) and minimum escapement goals (2-6 million) were only met during two of eight years (Fair 2003, Morstad and Baker 2006, Sands et al. 2008). The Bristol Bay region was declared an economic disaster by the federal government due to poor salmon runs in 1997 and 1998 and by the State of Alaska due to poor salmon runs and low prices in 1997, 1998, 2001, and 2002. Annual subsistence harvests declined from a mean of 75,000 salmon during 1974 – 1995, to a mean of 47,496 salmon during 1997 – 2006 (Fall et al. 2007, Sands et al. 2008). Annual commercial harvests fell from a mean of 8.1 million during 1980 – 1995 to a mean of 1.4 million during 1996 – 2003 (Morstad and

Baker 2006). Annual sport fish harvests also declined due to fishing closures and bag limit reductions (e.g., ADFG 2001 and 2002). Depressed runs to the Kvichak River have resulted in decreased spawning escapements (Figure 2) and failure to meet minimum escapement goals. Salmon production, measured by the number of adults produced by each spawning sockeye salmon has also declined, implying a slow recovery rate (Ruggerone and Link 2006).

The Kvichak River watershed contains two large lake systems, Lake Clark and Iliamna Lake, in which sockeye salmon spawn and rear (Figure 1). Lake Clark is a smaller watershed (9,583 km^2) than Iliamna Lake (11,137 km^2) and is also less productive due to the influence of active glaciers that make it colder and more turbid than Iliamna Lake (Demory et al. 1964, Mathisen and Poe 1969). Despite these characteristics, the Lake Clark watershed has at least 35 known spawning stocks (Woody et al. 2003, Young 2004, Young and Woody 2007a), and has comprised 7–30% (0.2-3.1 million) of the total Kvichak River escapement (Poe and Rogers 1984, Woody 2004, Young and Woody 2009).

Several studies have previously monitored Lake Clark sockeye salmon escapement, and the longest time series of data consists primarily of aerial escapement estimates collected since 1955 (Demory et al. 1964, Anderson 1968, Parker and Blair 1987, Regnart 1998). Such data provide some indication of relative peak spawner abundance in select clear water tributaries, but typically underestimate actual escapement (Jones et al. 1998). A recent study by Young and Woody (2007a) indicates that up to 60% of Lake Clark sockeye salmon spawn in turbid waters and cannot be seen from the air. Past escapement indices conducted on the lower Newhalen River (river kilometer 1) from 1979 – 1999 and from 2001 – 2002 provide an indicator of run timing and strength into the Newhalen River relative to Kvichak River escapement, but data are less reliable in years of high water and high salmon escapement as both affect count accuracy (Poe and Mathisen 1981; Rogers and Poe 1984, Poe and Rogers 1984; Rogers 1999, Woody 2004). Total escapement estimates derived from the index count range from 0.2 – 8.4 million sockeye salmon. Poe and Rogers (1984) used counting towers from 1980 – 1984 on the upper Newhalen River to provide a better estimate of total sockeye salmon escapement to Lake Clark, and reported Lake Clark escapements ranging from about 0.2 – 3.1 million fish. Woody (2004) used the same site and protocols to monitor Lake Clark escapement from 2000 – 2003, and reported escapements ranging from about 0.2 – 0.3 million fish, which represented an 81% decline compared to past studies. Young and Woody (2009) monitored the Lake Clark escapement at the Newhalen River counting tower from 2004 – 2007, and reported escapements ranging from 0.5 – 0.7 million fish, which showed an increasing trend in abundance.

STUDY AREA

The Newhalen River watershed is located in southwest Alaska within the Kvichak River watershed and includes the Newhalen River, Sixmile Lake, Tazimina River, and Lake Clark (Figure 1). The Newhalen River is a clear-water tributary of Iliamna Lake with a length of 40 km and mean July flow between 16,000 and 26,000 cubic feet per second (cfs) and a maximum July flow of 36,000 cfs (USGS 2009). A series of rapids and waterfalls located at river kilometer 11 affects salmon migration rates and during years of extremely high flows (> 28,000 cfs) creates a barrier to upstream migration (Poe and Rogers 1984). Sixmile Lake is a clear-water lake that is 10 km long and 1-2.5 km wide with an average depth of 5 m and a maximum depth of 35 m (NPS unpublished data). The Tazimina River is a clear-water tributary to Sixmile Lake with a length of about 87 km and a drainage area of approximately 829 km^2. Water from the upper portion of the watershed drains through two lakes, pours over a 30 m waterfall (river kilometer 15), flows through a canyon (~ 1.6 km) and finally winds 13.7 km through a low gradient (~3%) braided floodplain to its outlet in the upper Newhalen River. The Lake Clark watershed, located approximately 50 km upstream from Iliamna Lake and connected to it by Sixmile Lake and the Newhalen River to the southwest, includes Lake Clark and six primary tributaries. Lake Clark is the sixth largest lake within Alaska, the largest lake within Lake Clark National Park and Preserve, and is a semi-glacial oligotrophic lake that is 66 km long and 5-8 km wide with an average depth of 103 m, a maximum depth of 240 m, and a drainage area of 7,620 km^2 (Anderson 1969; Wilkens 2002). Of its six major tributaries, three are glacier fed, two are clear, and one is organically stained (Brabets 2002). Seasonal runoff from glacial tributaries is highest between June and September, and creates a turbidity gradient along the length of the lake from the turbid upstream end to the relatively clear downstream end (Brabets 2002; Wilkens 2002).

The Newhalen River watershed is a significant producer of sockeye salmon (0.2-3.1 million fish/year; Poe and Rogers 1984; Woody 2004, Young and Woody 2009) and contains at least 35 known spawning areas (Woody et al. 2003, Young and Woody 2007a). Primary spawning areas include the Tazimina River, Lake Clark outlet, shoreline beaches of Lake Clark and Little Lake Clark, Kijik Lake, Currant Creek, and the Tlikakila River (Regnart 1998, Young 2004, Young and Woody 2007a).

OBJECTIVES

1) Estimate sockeye salmon escapement to Lake Clark.
2) Determine age and size composition of the Lake Clark escapement

METHODS

Lake Clark Sockeye Salmon Escapement

Lake Clark sockeye salmon escapement estimates were made at river kilometer 36 (Figure 3) on the Newhalen River, using standard counting tower protocols outlined in Anderson (2000) and Woody (2007). We used the same site and specific procedures outlined by Poe and Rogers (1984) and used by Woody (2004) and Young and Woody (2009). Systematic, hourly, 10 minute counts were made from 6 m towers on both banks between late June and mid August. Night counts (0000 – 0400 hours) were made using rheostat controlled 12 volt lights powered by solar charged car batteries. Problem bears in camp disrupted counting operations throughout the 2008 field season, and night counting (0000 – 0400) was stopped for the remainder of the season beginning on July 26 to avoid possible dangerous bear encounters in the dark. Counting was terminated for the season when daily escapement was less than one percent of the total escapement for at least three consecutive days (Anderson 2000).

Data analyses included calculations for hourly and daily escapement, missed counts, lag time from the Kvichak River, run time, and run duration. Ten minute counts were expanded by a factor of six to yield an estimate of hourly escapement past the counting towers. Daily escapement was the sum of the 24 hourly estimates. Values for missed counts were estimated using a regression estimate based on previous years of data, which was similar to the method used by Poe and Rogers (1984). Lag time between the Kvichak River and Newhalen River escapements was estimated by comparing the date when each escapement estimate reached the 50^{th} percentile. Run timing, including the date each escapement reached the 1^{st}, 50^{th}, and 99^{th} percentile, was estimated using the cumulative daily escapement divided by total escapement. Run duration was estimated as the number of days elapsed between the 1^{st} and 99^{th} percentile of the total escapement.

Variance was estimated by considering tower counts as a systematic sample and then applying relevant methods developed for such sampling designs (see Reynolds et al. 2007). Variance estimator '5' in Wolter (1984) was used because of its robustness against underlying autocorrelation, stratification, and nonlinear trends (Reynolds et al. 2007). To estimate variance, the seasonal mean count per observation period was calculated, expanded to a mean hourly count based on observation period length and number of hours observed per day, and then multiplied by the number of days in the observation season (see Woody 2004). Run duration was calculated as the number of days elapsed between the 1^{st} and 99^{th} percentile of the total escapement.

Lake Clark Sockeye Salmon Age and Size Composition

Age and size composition of the Lake Clark escapement were determined by sampling pre-spawning sockeye salmon from the subsistence fishery in Sixmile Lake (Figure 3) and by sampling post-spawning fish from Lake Clark spawning areas, including Tazimina River, using seines (Appendix 1). Otoliths were extracted and ages were determined by NPS personnel. Lengths were measured from mid-eye to hypural plate (MEH) in millimeters. To make these data comparable with to mid-eye to fork lengths (MEF) collected by ADFG, MEH measures were converted to MEF estimates using regression equations derived by Woody (2004). These equations were derived from 1005 paired measures of MEH and MEF collected in 2000 and 2001.

The conversion equation for females ($r^2 = 0.96$; SE = 8.32) was:

$$MEF = 25.95 + 1.07 * MEH \tag{1}$$

The conversion equation used for males ($r^2 = 0.96$; SE = 8.1) was:

$$MEF = 27.8 + 1.06 * MEH \tag{2}$$

Chi square tests ($\alpha = 0.05$) were used to test for differences in age composition among sockeye samples from Lake Clark spawning areas including the Tazimina River, the Sixmile Lake subsistence fishery, and Tazimina River spawning area. When sample sizes were below 10 in the chi square comparison, that category was dropped from the age analysis.

Sizes at age and by sex were compared for samples from the subsistence fishery and Lake Clark spawning areas using Kruskal-Wallis one-way ANOVA on ranks ($\alpha = 0.05$); Dunn's method was applied when the test was significant (Zar 1984).

Environmental and Hydrological Observations

Surface water temperature and stream discharge data were collected at the Newhalen River counting towers. Water temperature was recorded every two hours during escapement monitoring with a Stowaway Tidbit temperature logger (Onset Computer Corporation, Bourne, Massachusetts) and an average daily water temperature was calculated. Staff gauge measurements at the counting tower site were used to estimate stream discharge in the Newhalen River as described by Poe and Rogers (1984). The regression equation derived by Poe and Rogers (1984) used to calculate equivalent stage height/discharge at the USGS gage on the Newhalen River was:

$$Y = .9759 + .8143(x) \tag{3}$$

RESULTS AND DISCUSSION

Lake Clark Sockeye Salmon Escapement

Lake Clark escapement during 2008 was 472,962 fish (95% CI: 445,620 to 700,524 fish), and comprised 17% of the total Kvichak River escapement (Figure 4). Compared to past studies, the 2008 escapement was 20% less than the mean escapement during 2004-2007 (Young and Woody 2009), 219% more than the mean escapement during 2000-2003 (Woody 2004), and 58% less than the mean escapement during 1980-1984 (Poe and Rogers 1984) (Figure 5). Annual Lake Clark escapements have been fairly stable since 2004. The Lake Clark contribution to the total Kvichak escapement was very similar to that documented for previous years. It was only 2% lower than the mean contribution during 2000-2007 and 1% higher than the mean contribution during 1980-1984 (Appendix 2).

Sockeye salmon escapement past the Newhalen River towers began around July 1, ended by the middle of August, and lagged behind the Kvichak River escapement by 11 days (Figures 6-10, Appendix 3). The timing of the run was similar to most previous years (Figure 6 and 7), but the duration of the run was nine days longer than the median run duration since 2000 (Figure 11). Since the duration of the run passing the Kvichak River towers was not protracted (ADFG) and the travel (lag) time between the Kvichak and Newhalen tower sites was actually two days less than the average of 13 days, it is difficult provide an explanation for the protracted duration of the run passing the Newhalen tower site.

Patterns in bank orientation and diurnal migration were similar to past observations at the Newhalen River towers and at other sites within Bristol Bay (Becker 1962, Poe and Rogers 1984, Anderson 2000, Young and Woody 2009). During the 2008 season, about 90% of the salmon migrated upstream past the left bank tower, peak migration occurred between the hours of 0800 and 2000, and counts at night (between the hours of 0000 and 0400) were less than 4% of the total daily escapement (Figure 12, Appendix 4).

Lake Clark Sockeye Salmon Age and Size Composition

A total of 1,156 sockeye salmon were sampled from the local Sixmile Lake subsistence fishery and from Lake Clark spawning areas. Fish sampled from the subsistence fishery were 79% age 1.2 and 21% age 1.3 while fish sampled from spawning areas were 34% age 1.2, 65% age 1.3, 1% age 2.2, and <1% age 2.3 (Table 1). The age composition of the sample from the Sixmile Lake subsistence fishery was significantly different ($p<0.001$) from the sample from spawning areas (Figure 13, Table 1). The subsistence fishery sample age composition was not significantly different ($p=0.25$) from either the Tazimina River or the Kvichak River escapement sample (Jones et al. 2009; Figure 13, Table 1).

Comparisons among age composition of samples yielded similar results to those from previous years (Woody 2004, Young and Woody 2009). This suggests, as indicated by Young and Woody (2009), the Sixmile Lake subsistence fishery is primarily harvesting sockeye salmon bound for the Tazimina River. It also appears that the age composition of sockeye salmon spawning in Lake Clark, with the exception of the Tazimina River, is different from that of sockeye salmon spawning in Lake Iliamna.

For all sockeye salmon sampled, MEF length ranged from 437 to 639 mm (Figure 14), and median MEF length was 532 mm (Table 2). Sockeye salmon sampled from the subsistence fishery were generally larger at age for both sexes than those sampled at Lake Clark spawning areas (Figures 15 and 16), and males were significantly larger ($p<0.05$) than females for all age classes.

Environmental and Hydrological Observations

Water temperature and stream discharge during the operation of the Newhalen River counting tower ranged from 7.5 to 11.4° C (average, 9.7° C) and 18,460 – 20,370 ft^3/sec (average, 19,929 ft^3/sec) (Figures 17 and 18, Appendix 5). Water temperatures were similar to those recorded at this site in previous years (Poe and Rogers 1984, Young and Woody 2009) as well as to those documented for other sockeye salmon systems (Hodgson and Quinn 2002).The peak summer flow during 2008 was similar to peak flows recorded at this site since 2000 (Young and Woody 2009, NPS unpublished data), but was generally lower than flows measured by Poe and Rogers (1984) and well below the extremely high flows of 1980 (28,000 – 32,568 ft^3/sec) that created a velocity barrier to upstream passage of sockeye salmon on the Newhalen River.

ACKNOWLEDGEMENTS

This work was made possible through funding from the U.S. Fish and Wildlife Service, Office of Subsistence Management; through the Fisheries Resource Monitoring Program under an agreement for project 08-402. The National Park Service provided additional funding and logistical support. Joel Reynolds, U.S. Fish and Wildlife Service, assisted with statistical analyses.

This project would not have been possible without the support and participation of the wonderful people of Nondalton. Special thanks to June and Bob Tracy who continue to provide a base camp for all tower operations. Olga, Kristy, and Tara Balluta shared their home, provided meals and support to weary field crews. The Kijik Corporation permitted use of tribal lands for field operations and gave written support for this project. Special thanks to the Nondalton Tribal Council and Regional Advisory Council for their continued support.

Very special thanks go to the dedicated volunteers and staff who gave their time and boundless energy to this project: Tara Balluta, Sarah Evans, Beth McLain, Reilly Newman, Erika Partee, and Danielle Stickman.

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FIGURES AND TABLES

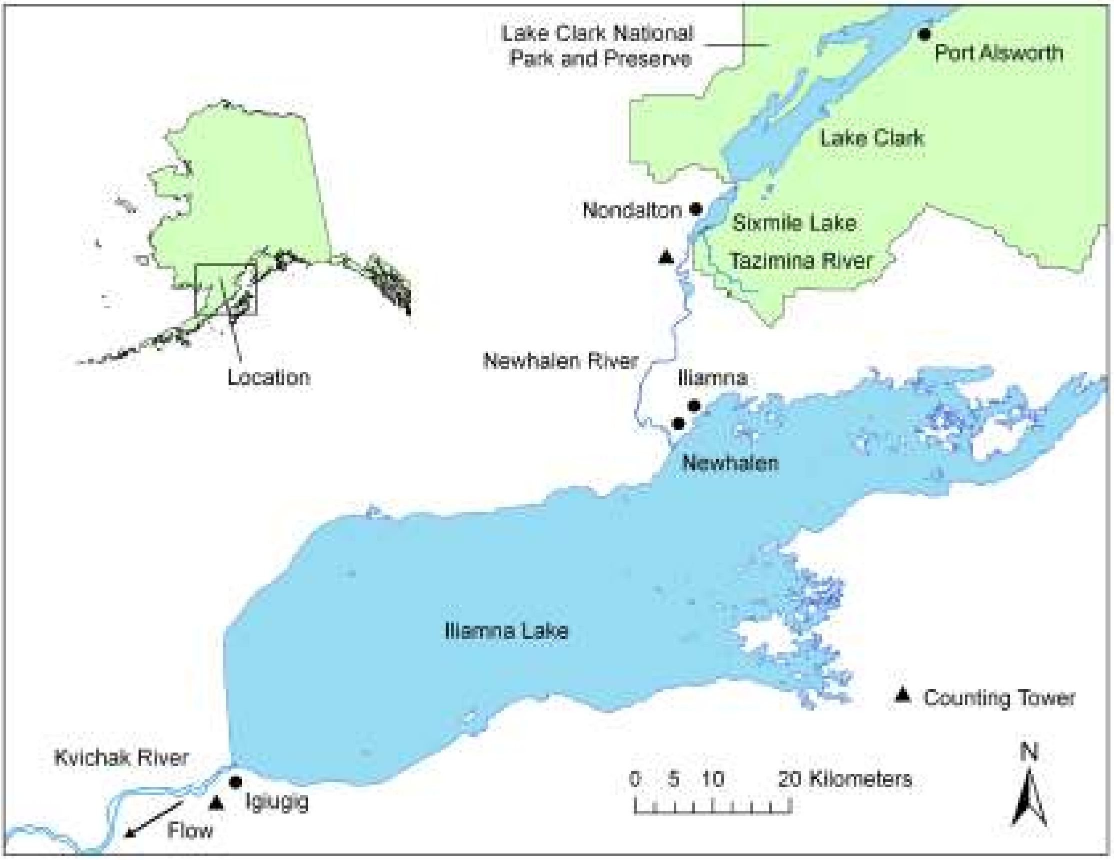

Figure 1. Location of the Kvichak and Newhalen River counting towers within the Kvichak River drainage. The counting tower located near the community of Igiugig is operated by the Alaska Department of Fish and Game.

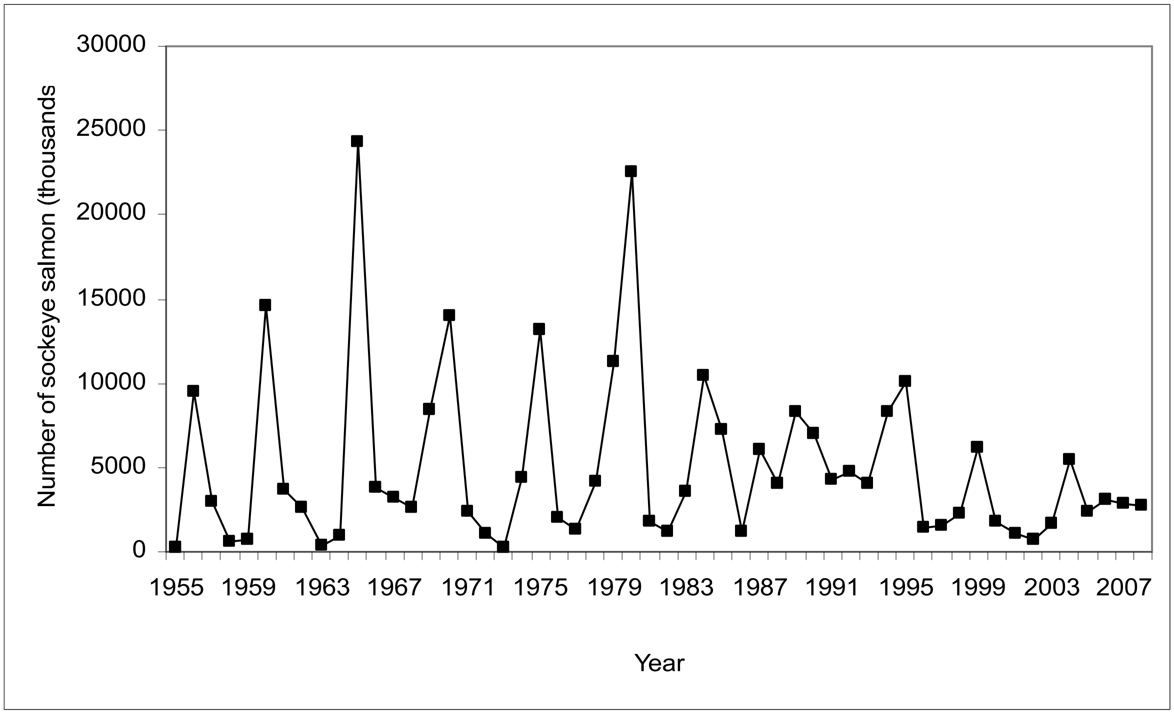

Figure 2. Annual sockeye salmon escapements to the Kvichak River, 1955 to 2008. Data from the Alaska Department of Fish and Game, Anchorage, Alaska (2009).

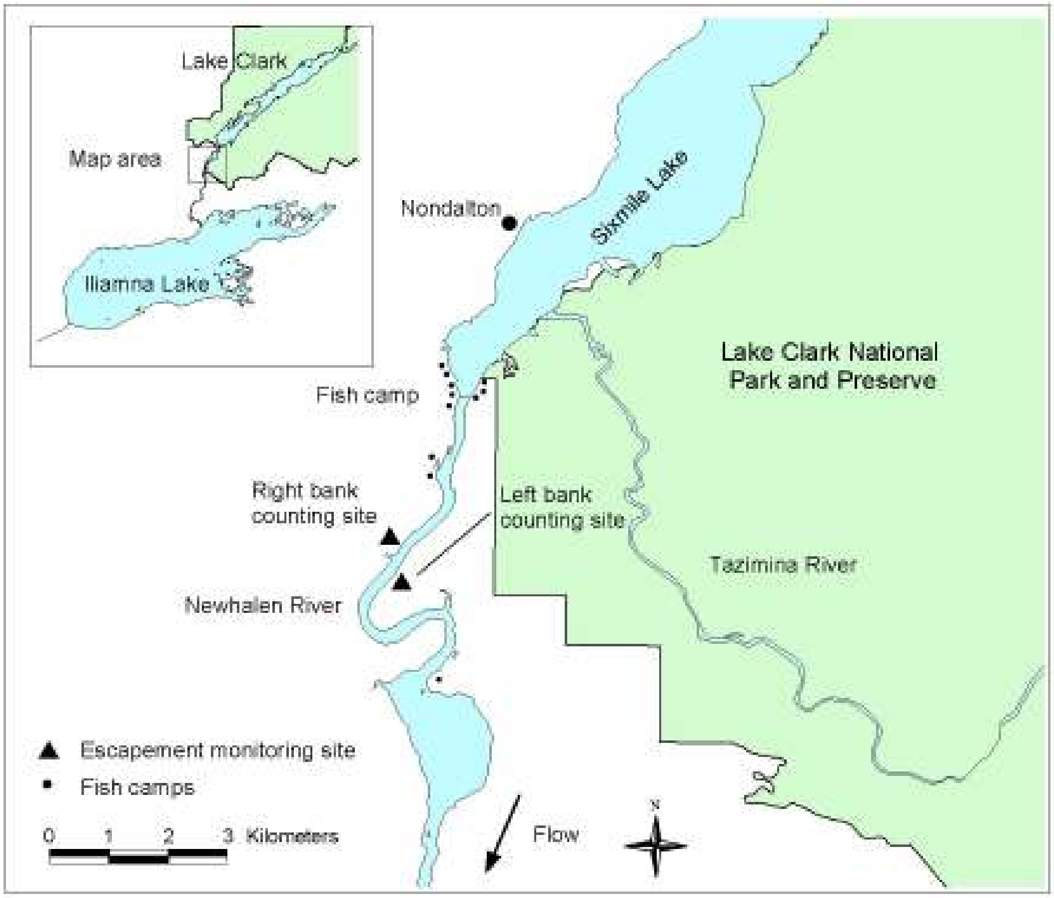

Figure 3. Location of the Newhalen River counting towers.

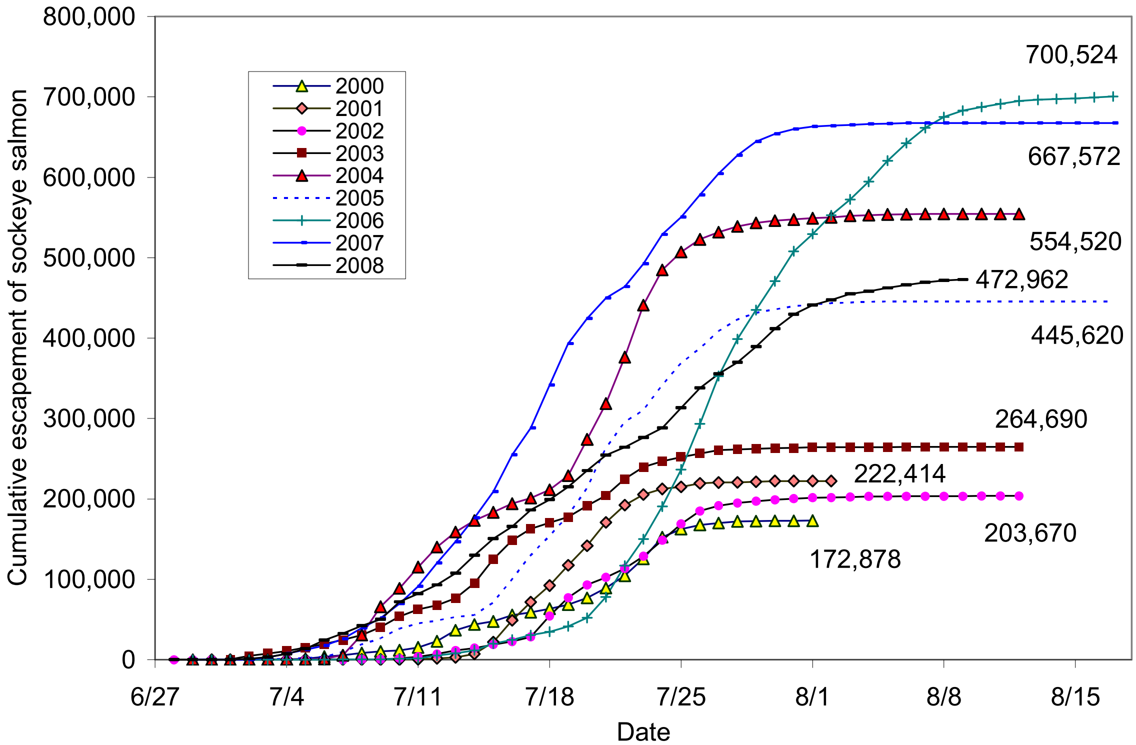

Figure 4. Cumulative escapement of sockeye salmon at the Newhalen River counting tower, 2000 – 2008. Data for 2000 – 2007 are from Woody (2004), and Young and Woody (2009).

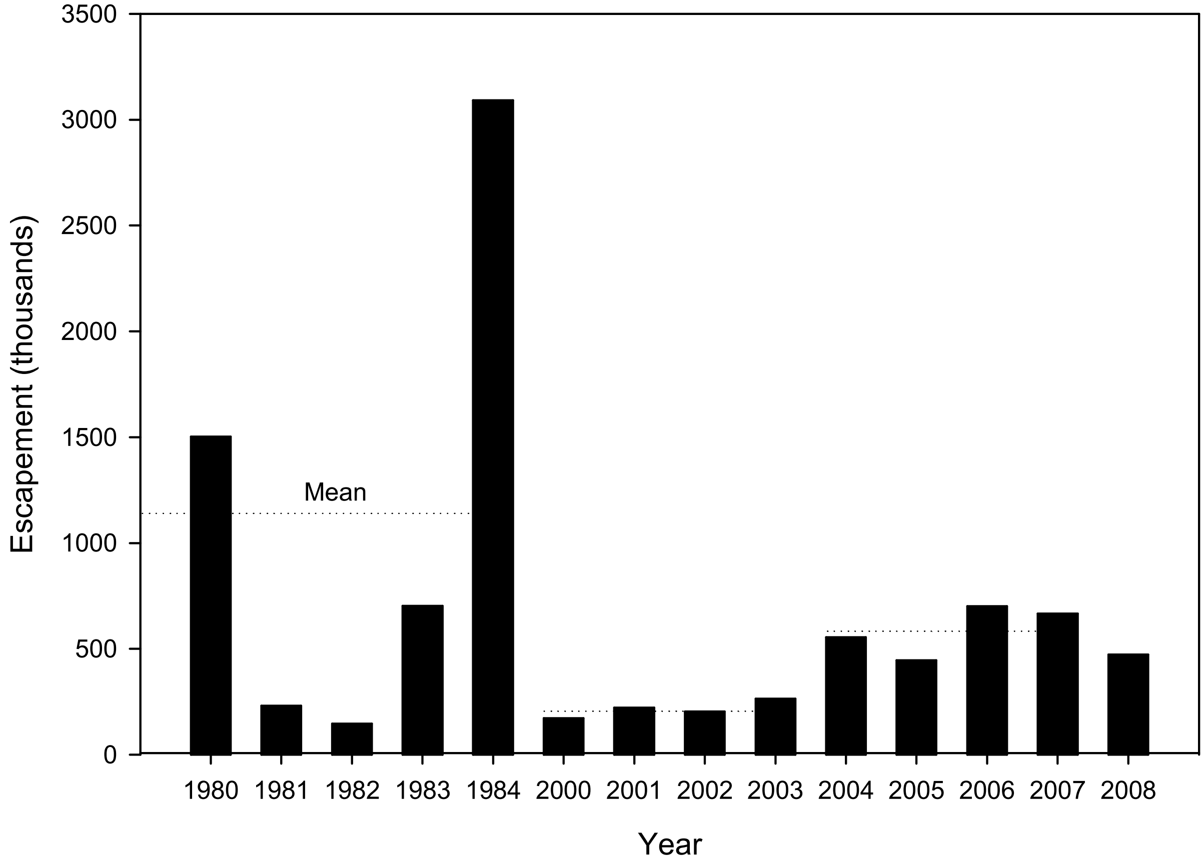

Figure 5. Newhalen River sockeye salmon escapement by year and four or five year means, 1980 – 1984 and 2000 – 2008. Data for 1980 – 2007 are from Poe and Rogers (1984), Woody (2004), and Young and Woody (2009).

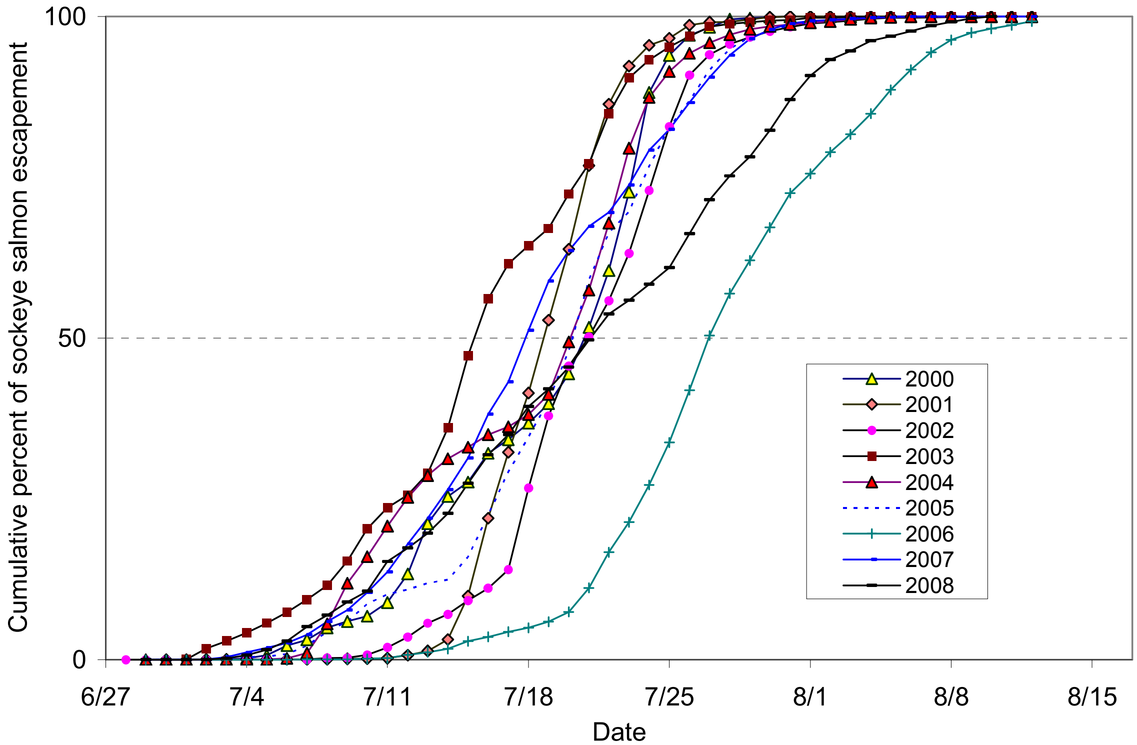

Figure 6. Cumulative percent of total sockeye salmon escapement to the Newhalen River by date, 2000 – 2008. Data for 2000 – 2007 are from Woody (2004) and Young and Woody (2009).

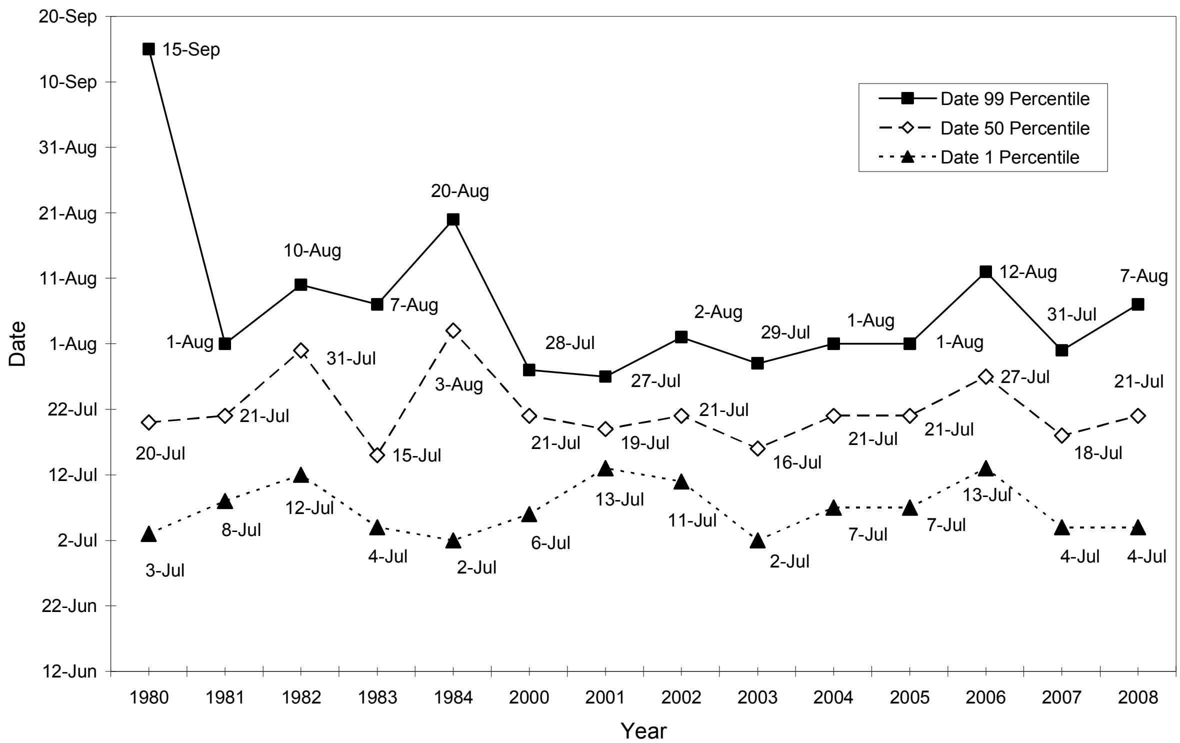

Figure 7. Newhalen River sockeye salmon escapement by year and percentile, 1980 – 1984 and 2000 – 2008. Data for 1980 – 2007 are from Poe and Rogers (1984), Woody (2004), and Young and Woody (2009).

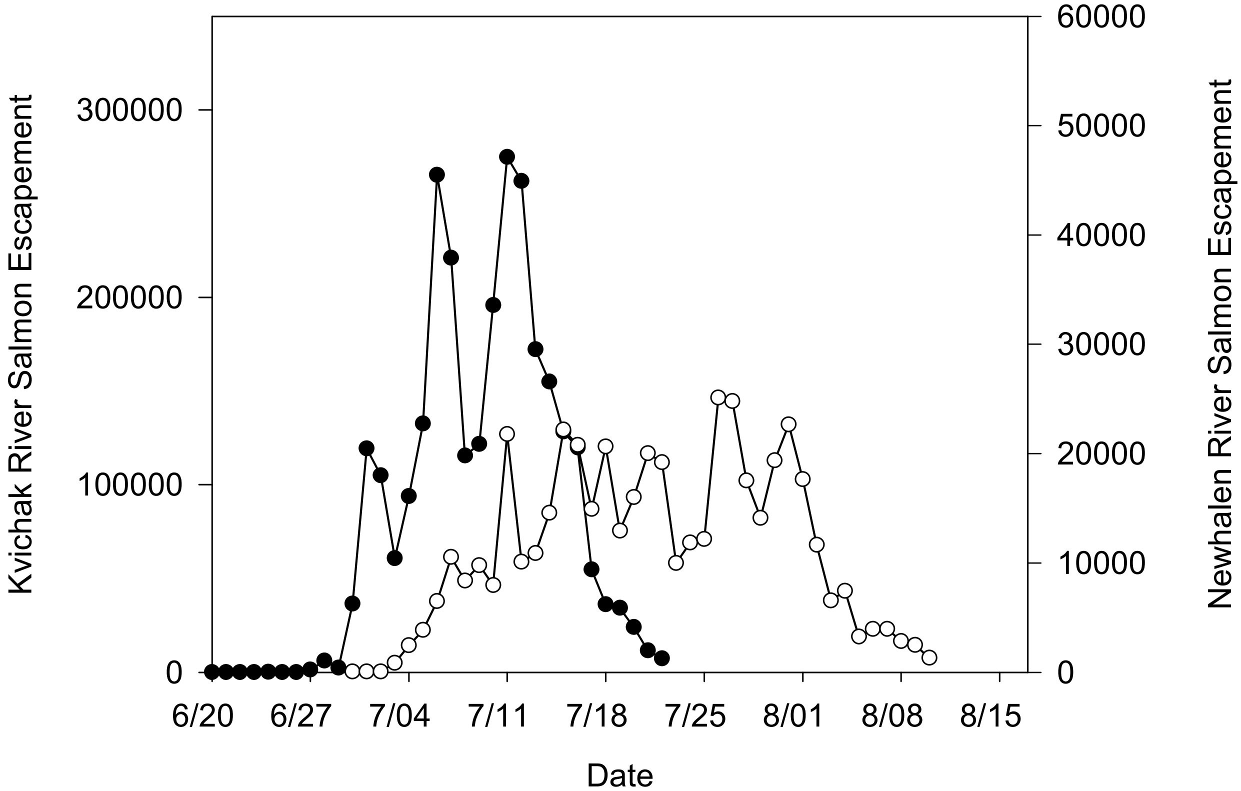

Figure 8. Daily sockeye salmon escapement to the Kvichak and Newhalen Rivers, 2008. Kvichak River data from the Alaska Department of Fish and Game, Anchorage, Alaska (2009).

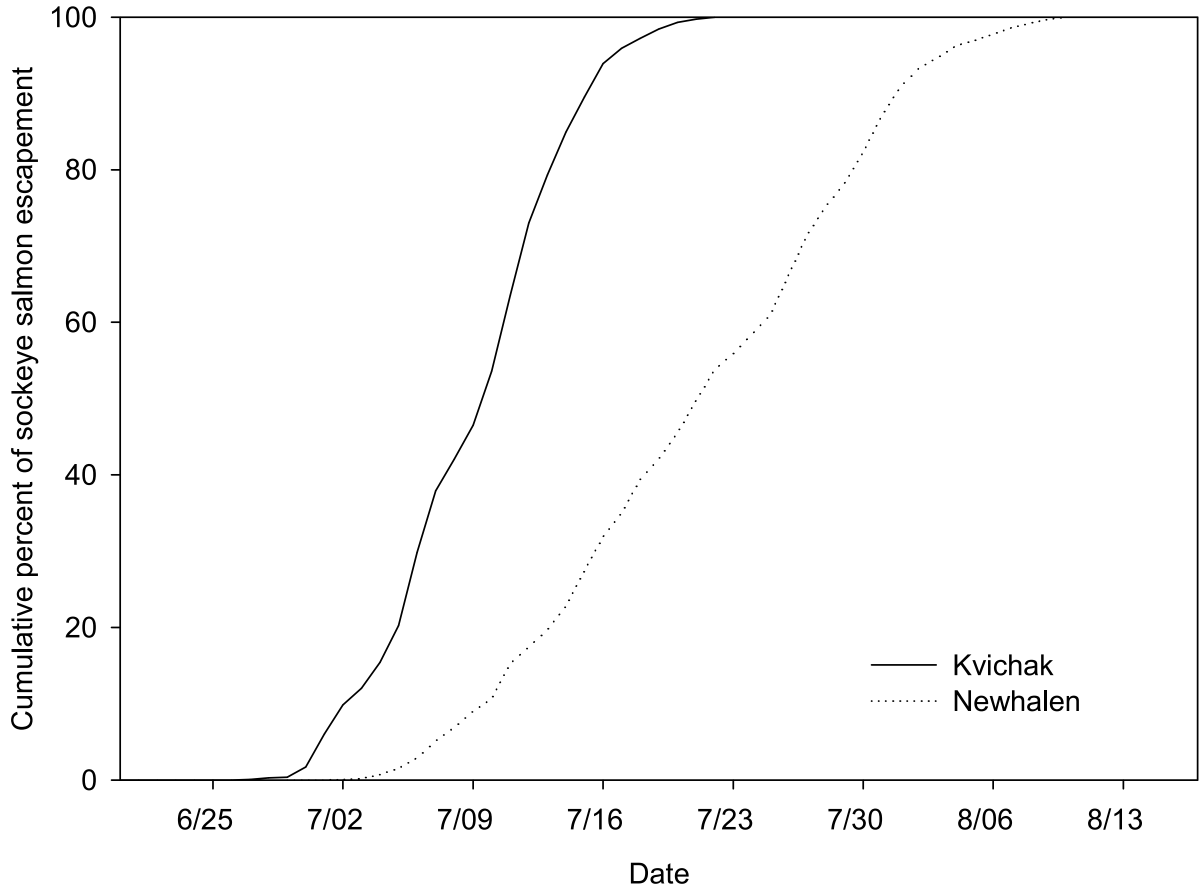

Figure 9. Cumulative percent of total sockeye salmon escapement to the Kvichak River and Newhalen River by date, 2008. Kvichak River data from the Alaska Department of Fish and Game (2009).

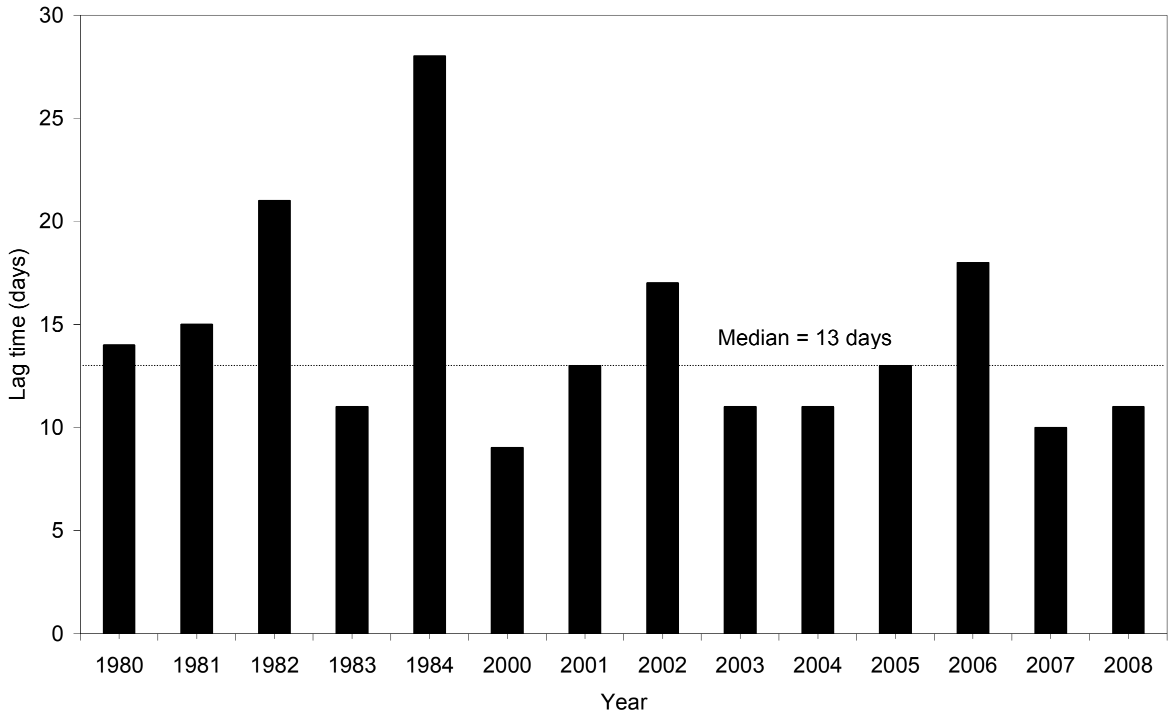

Figure 10. Lag time between the Kvichak River and Newhalen River escapements; estimated by comparing the date when each escapement estimate reached the 50th percentile, 1980 – 1984 and 2000 – 2008. Kvichak River data are from Alaska Department of Fish and Game (2009). Newhalen River data for 1980 – 2007 are from Poe and Rogers (1984), Woody (2004), and Young and Woody (2009).

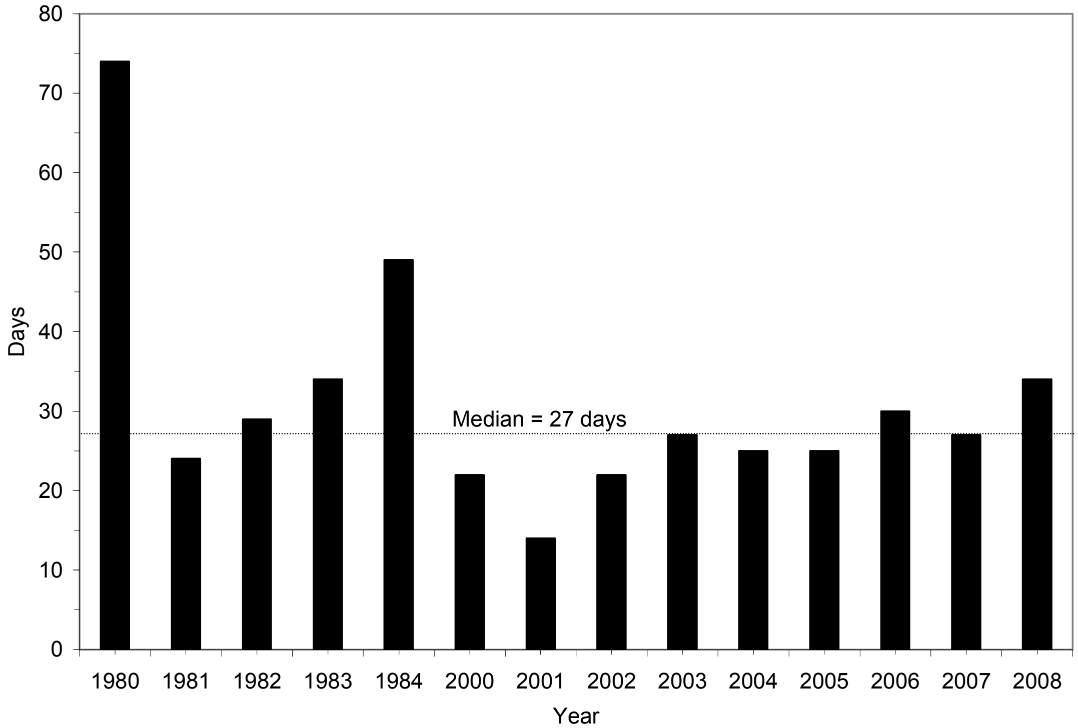

Figure 11. Newhalen River sockeye salmon run duration; number of days between 1st and 99th percentile, 1980 – 1984 and 2000 – 2008. Data for 1980 – 2007 are from Poe and Rogers (1984), Woody (2004), and Young and Woody (2009).

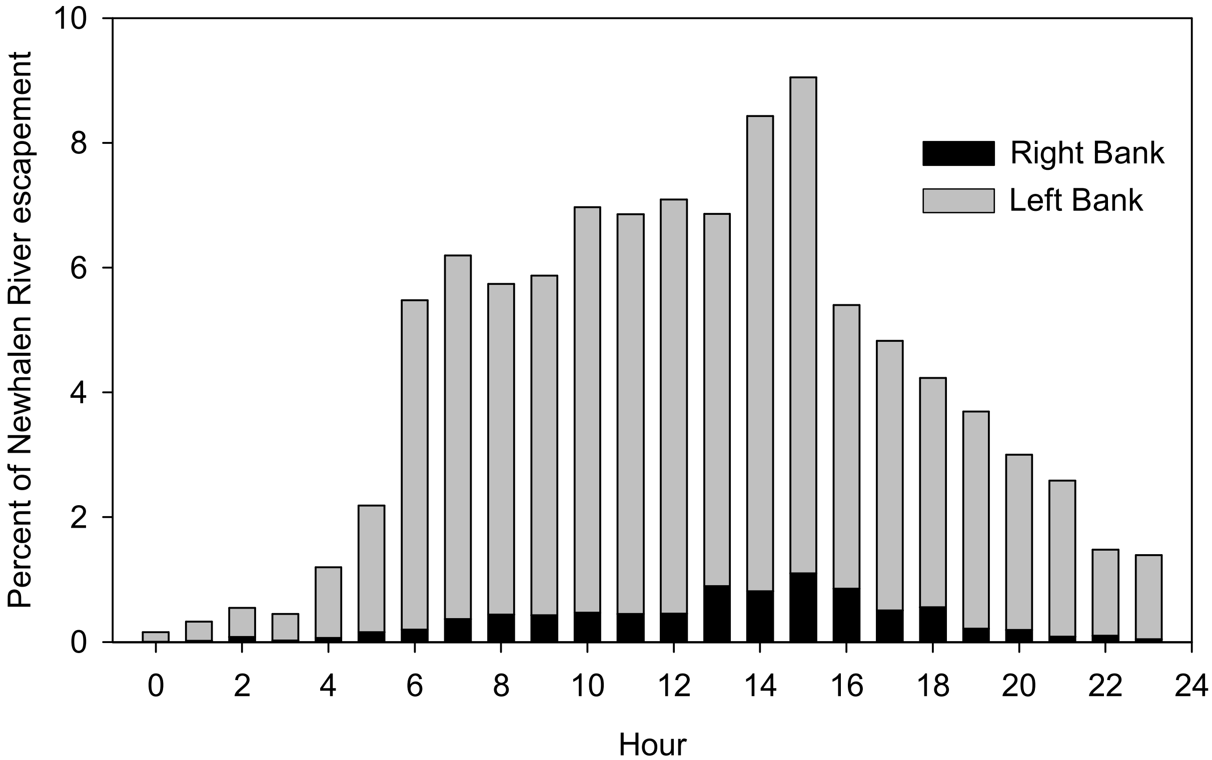

Figure 12. Percent of sockeye salmon counted at the Newhalen River counting towers by hour and bank (looking downstream), 2008.

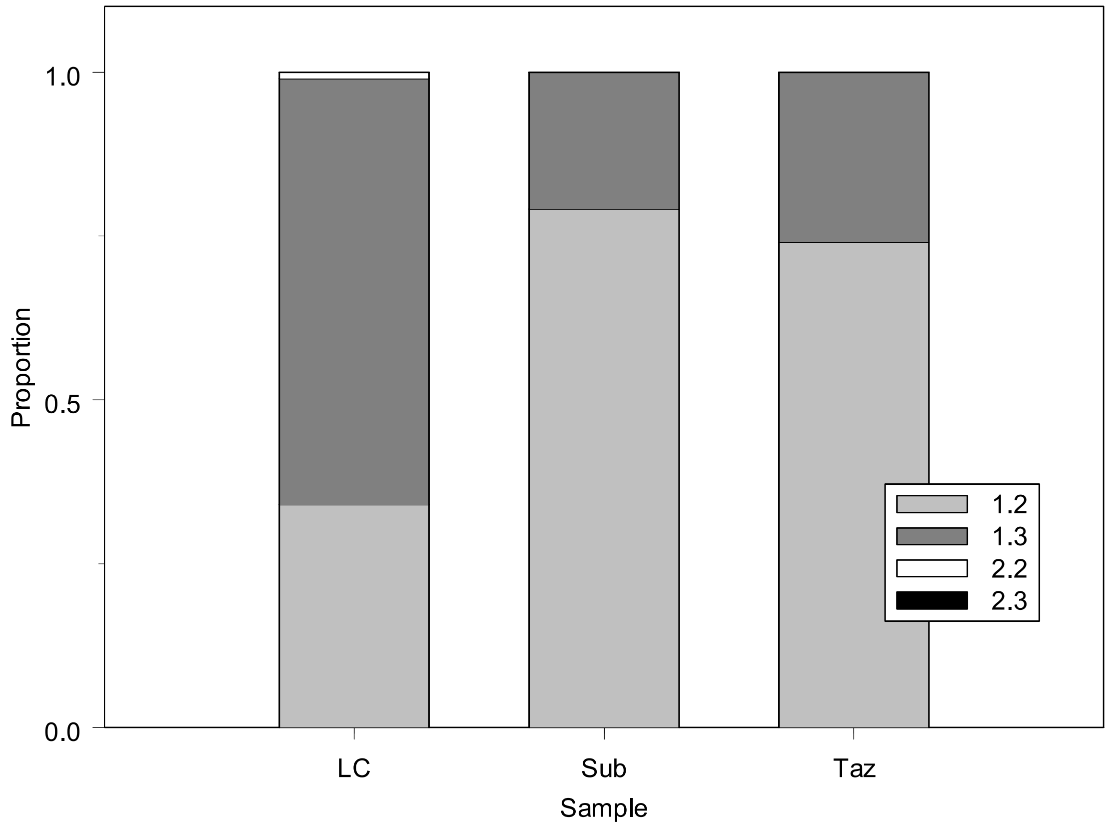

Figure 13. Age composition of sockeye salmon sampled from Lake Clark spawning areas including Tazimina River (LC), the Sixmile Lake subsistence fishery (Sub), and the Tazimina River spawning area (Taz), 2008.

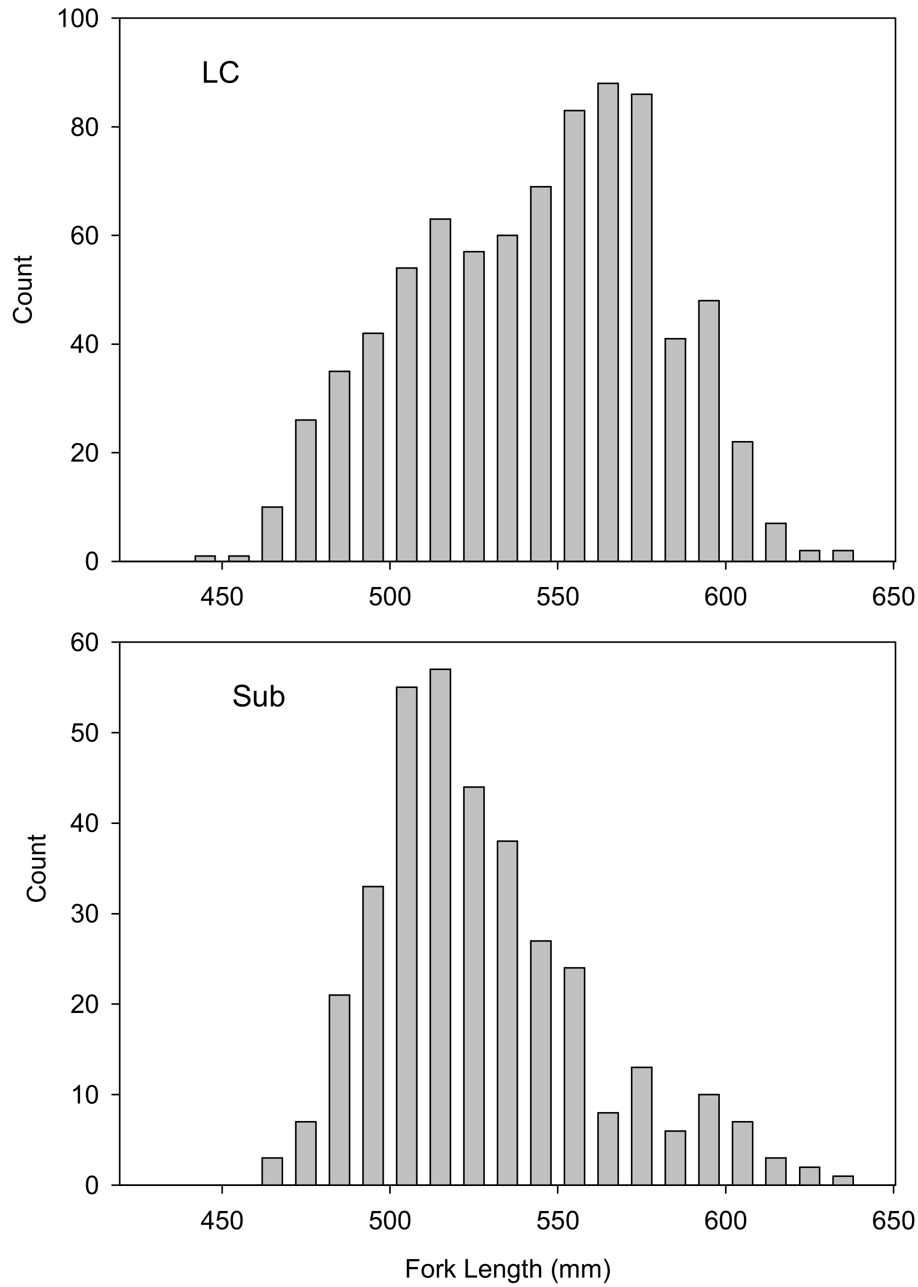

Figure 14. Length frequency distribution of sockeye salmon sampled from Lake Clark spawning areas (LC) and the Sixmile Lake subsistence fishery (Sub), 2008.

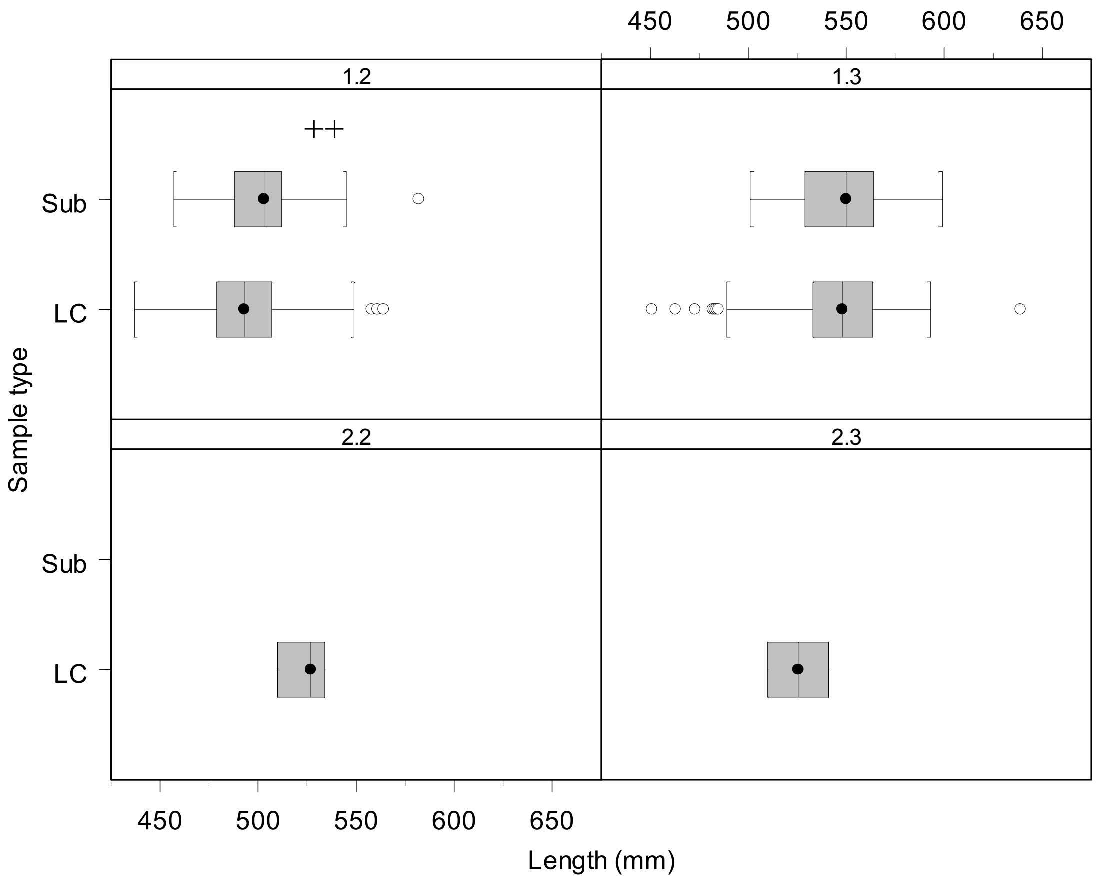

Figure 15. Box and whisker plots of mid-eye to fork length (mm) data by age class for female sockeye salmon sampled from Lake Clark spawning areas (LC) and the Sixmile Lake subsistence fishery (Sub), 2008. Shaded box = central 50% of data, filled circle within box = median value, lines with horizontal bars = range of data points that are within 1.5 times the interquartile range from either end of the box, ,and open circles = outlier data points that are more than 1.5 times the interquartile range from either end of the box. Statistically significant differences ($p<0.05$) are indicated with ++.

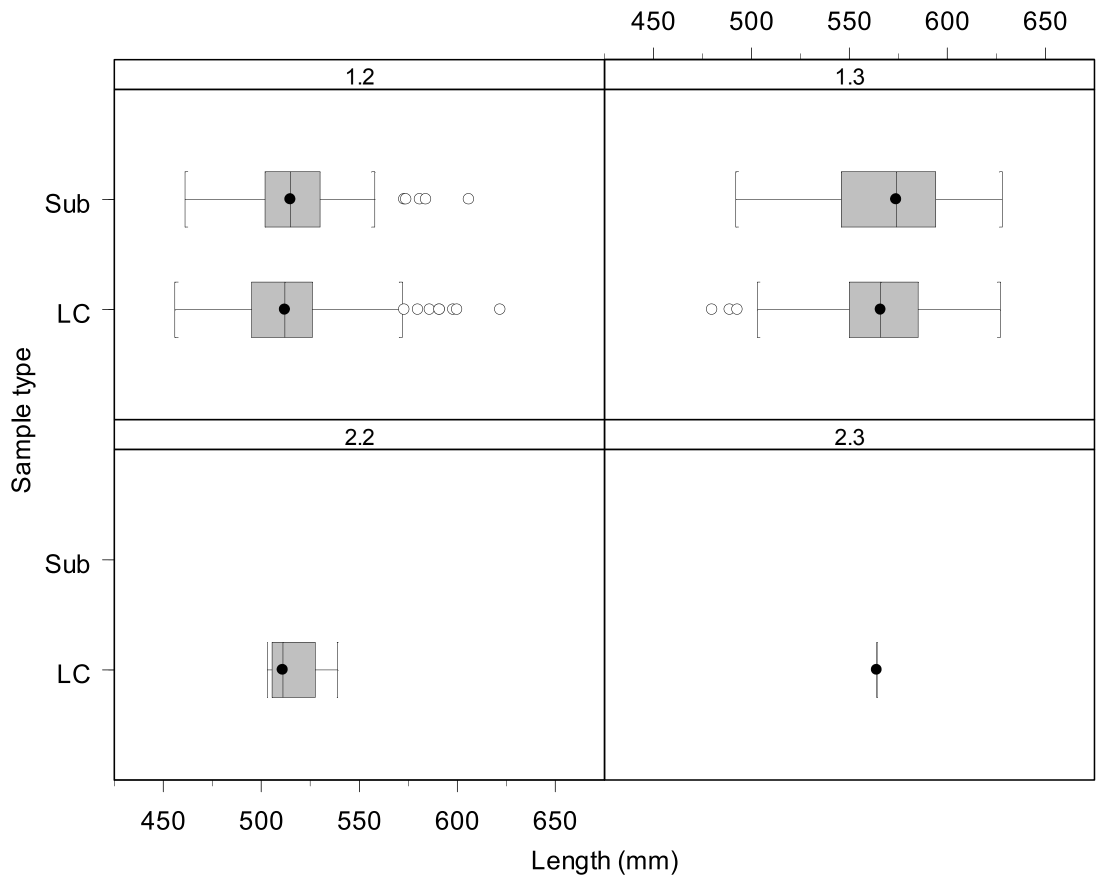

Figure 16. Box and whisker plots of mid-eye to fork length (mm) data by age for male sockeye salmon sampled from Lake Clark spawning areas (LC) and the Sixmile Lake subsistence fishery (Sub), 2008. Shaded box = central 50% of data, filled circle within box = median value, lines with horizontal bars = range of data points that are within 1.5 times the interquartile range from either end of the box, ,and open circles = outlier data points that are more than 1.5 times the interquartile range from either end of the box.

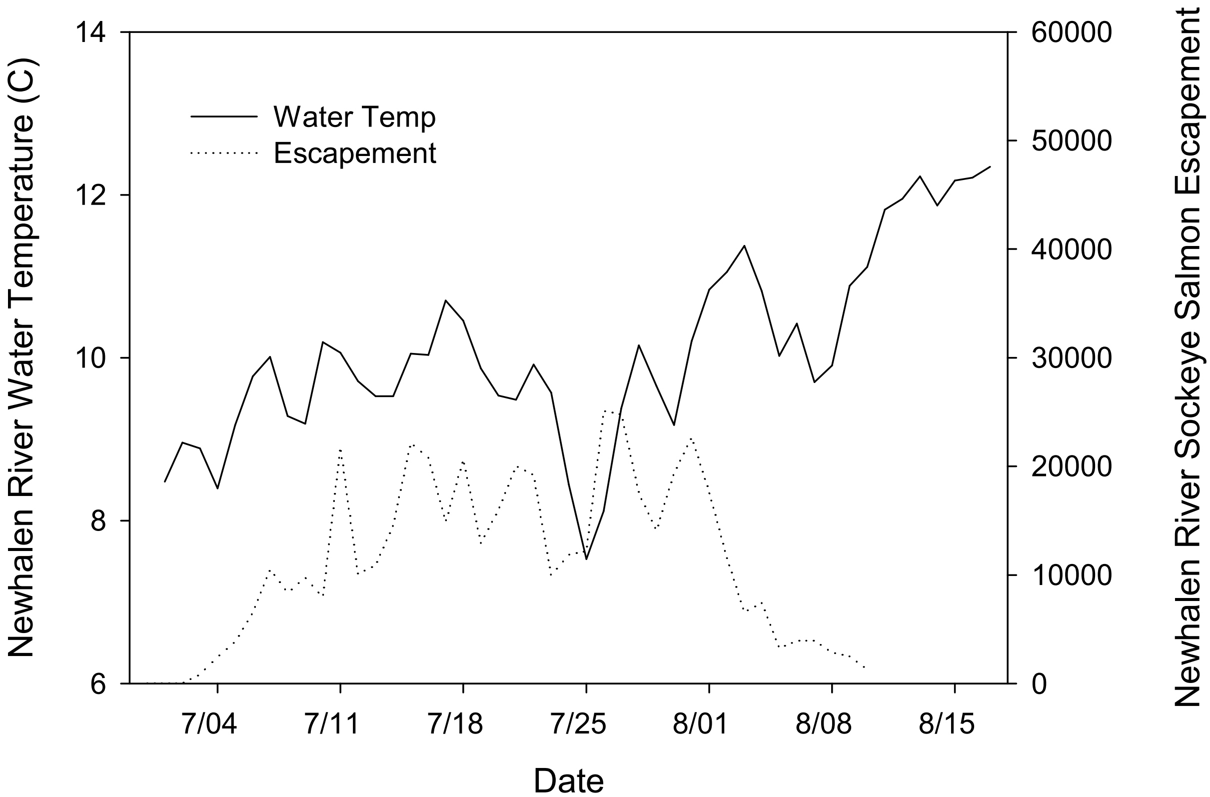

Figure 17. Daily average water temperature and sockeye salmon escapement recorded at the Newhalen River counting tower, 2008.

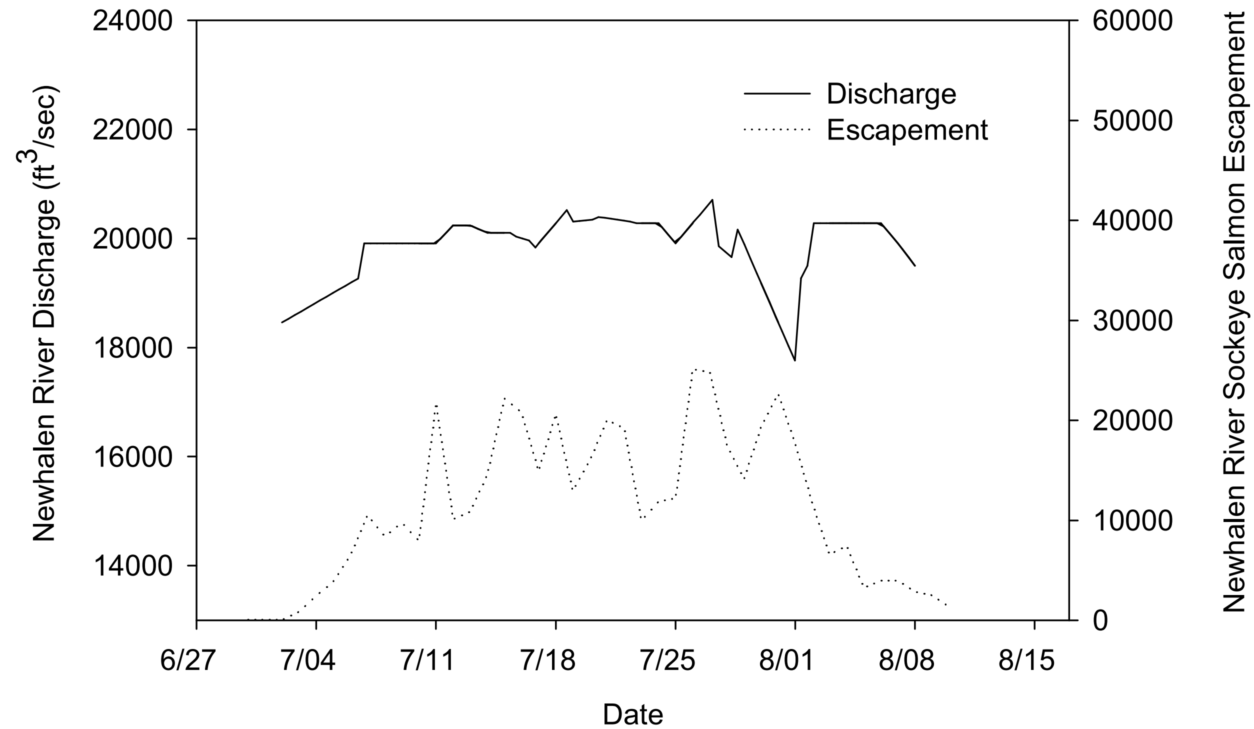

Figure 18. Estimated Newhalen River discharge (ft^3/sec) and sockeye salmon escapement recorded at the Newhalen River counting tower, 2008.

Table 1. Age composition of salmon captured from Lake Clark spawning areas including Tazimina River (LC), the Sixmile Lake subsistence fishery (Sub), and the Tazimina River spawning area (Taz), 2008. Sample sizes (n) and percentage composition (%) are shown.

	LC		Sub		Taz	
Age	n	%	n	%	n	%
1.2	269	33.8	284	79.1	76	74.3
1.3	514	64.5	75	20.9	26	25.7
2.2	11	1.4	0	0.0	0	0
2.3	3	0.4	0	0.0	0	0
All	797	100.0	359	100.0	101	100.0

Table 2. Median mid-eye to fork length (MEF; mm) by age for female (F) and male (M) sockeye salmon sampled from Lake Clark spawning areas (LC) and the Sixmile Lake subsistence fishery (Sub). Sample size for each category = Count.

	Age																
	1.2				1.3				2.2				2.3				
	F		M		F		M		F		M		F		M		
	LC	Sub	LC	Sub	LC	Sub	LC	Sub	LC	Sub	LC	Sub	LC	Sub	LC	Sub	All
MEF	493	503	512	515	548	550	566	574	527		511		525		564		532
Count	138	91	131	193	256	25	258	50	3		8		2		1		1156

APPENDIX

Appendix 1. Location and dates that Lake Clark spawning areas and the Sixmile Lake subsistence fishery were sampled in 2008. Latitude and longitude coordinates are reported in decimal degrees and WGS 84 datum.

Water Body	Location	Latitude	Longitude	Dates
Lake Clark	Chi Point	60.075562	-154.604218	9/18 - 9/26
Lake Clark	Chulitna Lodge	60.280749	-154.264898	9/20 - 10/8
Lake Clark	Hatchet Point	60.374555	-153.914123	9/26 - 10/8
Kijik Lake	Kijik Lake	60.287034	-154.344779	9/23 - 10/17
Little Kijik River	Little Kijik River	60.307900	-154.293283	9/24 - 10/17
Little Lake Clark	Little Lake Clark	60.418352	-153.696577	9/30 - 10/26
Sixmile Lake	Sixmile Lake	59.943740	-154.866530	7/4 - 7/29
Sucker Bay Lake	Sucker Bay Lake	60.021547	-154.663638	9/1 - 9/14
Tazimina River	Tazimina River	59.931333	-154.813772	8/31 - 9/10

Appendix 2. Lake Clark and Kvichak River sockeye salmon escapement, 1980-1984 and 2000-2007. Kvichak River data are from the Alaska Department of Fish and Game (2009).

	Escapement		
Year	Lake Clark[abc]	Kvichak River[d]	% of Kvichak
1980	1,502,898	22,505,268	7
1981	231,714	1,754,358	13
1982	147,294	1,134,840	13
1983	702,792	3,569,982	20
1984	3,091,620	10,490,670	29
2000	172,902	1,827,780	9
2001	222,414	1,095,348	20
2002	203,682	703,884	29
2003	264,690	1,686,804	16
2004	554,520	5,550,134	10
2005	445,620	2,320,332	19
2006	700,524	3,068,226	23
2007	667,572	2,810,208	24
2008	472,962	2,757,912	17
1980 – 1984 Average	1,135,264	7,891,024	16
2000 – 2003 Average	215,922	1,328,454	19
2004 – 2007 Average	592,059	3,437,225	19
All year's Average	685,249	4,501,372	18

[a] 1980 - 1984 data from Poe and Rogers (1984)
[b] 2000 - 2003 data from Woody (2004)
[c] 2004 - 2007 data from Young and Woody (2009)
[d] Alaska Department of Fish and Game (2009)

Appendix 3. Daily estimates of sockeye salmon escapement for the Kvichak and Newhalen Rivers, 2008. Kvichak River escapement are from Alaska Department of Fish and Game (2009). Newhalen River counts from 26 July - 10 August were estimated using 20 hr counts that were expanded to 24 hr counts using historic passage rates.

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
6/20	42	42	0.00	0.00				
6/21	36	78	0.00	0.00				
6/22	36	114	0.00	0.00				
6/23	30	144	0.00	0.01				
6/24	132	276	0.01	0.01				
6/25	6	282	0.00	0.01				
6/26	60	342	0.00	0.01				
6/27	1,296	1,638	0.06	0.06				
6/28	6,084	7,722	0.26	0.28				
6/29	2,322	10,044	0.10	0.36				
6/30	36,558	46,602	1.58	1.69	36	36	0.01	0.01
7/1	119,400	166,002	5.15	6.02	36	72	0.01	0.02
7/2	105,030	271,032	4.53	9.83	36	108	0.01	0.02
7/3	60,804	331,836	2.62	12.03	852	960	0.18	0.20
7/4	93,840	425,676	4.04	15.43	2454	3,414	0.52	0.72
7/5	132,642	558,318	5.72	20.24	3858	7,272	0.82	1.54
7/6	265,296	823,614	11.43	29.86	6492	13,764	1.37	2.91
7/7	221,028	1,044,642	9.53	37.88	10524	24,288	2.23	5.14
7/8	115,488	1,160,130	4.98	42.07	8364	32,652	1.77	6.90
7/9	121,740	1,281,870	5.25	46.48	9768	42,420	2.07	8.97
7/10	195,756	1,477,626	8.44	53.58	7,956	50,376	1.68	10.65
7/11	274,878	1,752,504	11.85	63.54	21,762	72,138	4.60	15.25
7/12	261,954	2,014,458	11.29	73.04	10,092	82,230	2.13	17.39
7/13	172,236	2,186,694	7.42	79.29	10,872	93,102	2.30	19.68
7/14	154,908	2,341,602	6.68	84.90	14,568	107,670	3.08	22.77
7/15	128,316	2,469,918	5.53	89.56	22,164	129,834	4.69	27.45
7/16	119,868	2,589,786	5.17	93.90	20,784	150,618	4.39	31.85
7/17	54,786	2,644,572	2.36	95.89	14,916	165,534	3.15	35.00
7/18	36,174	2,680,746	1.56	97.20	20,634	186,168	4.36	39.36
7/19	34,302	2,715,048	1.48	98.45	12,936	199,104	2.74	42.10
7/20	24,054	2,739,102	1.04	99.32	16,008	215,112	3.38	45.48
7/21	11,490	2,750,592	0.50	99.73	20,028	235,140	4.23	49.72
7/22	7,320	2,757,912	0.32	100.00	19,188	254,328	4.06	53.77
7/23					9,978	264,306	2.11	55.88
7/24					11,850	276,156	2.51	58.39
7/25					12,186	288,342	2.58	60.97
7/26					25,104	313,446	5.31	66.27
7/27					24,780	338,226	5.24	71.51
7/28					17,514	355,740	3.70	75.22

-continued-

Appendix 3. Continued.

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
7/29					14,112	369,852	2.98	78.20
7/30					19,356	389,208	4.09	82.29
7/31					22,668	411,876	4.79	87.08
8/1					17,640	429,516	3.73	90.81
8/2					11,658	441,174	2.46	93.28
8/3					6,552	447,726	1.39	94.66
8/4					7,440	455,166	1.57	96.24
8/5					3,252	458,418	0.69	96.92
8/6					3,936	462,354	0.83	97.76
8/7					3,960	466,314	0.84	98.59
8/8					2,844	469,158	0.60	99.20
8/9					2,490	471,648	0.53	99.72
8/10					1,314	472,962	0.28	100.00
Totals		2,757,912		100.00		472,962		100.00

Appendix 4. Percent of fish counted at the Newhalen River counting towers by hour and bank, 2008. Left Bank (LB) and Right Bank (RB) orientation are for observer looking downstream.

	2008	
Hour	LB	RB
0	0.15	0.01
1	0.30	0.02
2	0.47	0.08
3	0.43	0.02
4	1.13	0.06
5	2.03	0.16
6	5.28	0.20
7	5.83	0.37
8	5.30	0.44
9	5.45	0.43
10	6.50	0.47
11	6.41	0.45
12	6.63	0.46
13	5.97	0.89
14	7.62	0.81
15	7.95	1.10
16	4.55	0.85
17	4.32	0.50
18	3.68	0.56
19	3.48	0.21
20	2.81	0.19
21	2.50	0.09
22	1.38	0.10
23	1.35	0.04
Total	91.50	8.50

Appendix 5. Daily average water temperature (C) and discharge (ft^3/sec) recorded at the Newhalen River counting tower, 2008.

Date	Water Temperature (C)	Discharge (ft^3/sec)
7/1	8.5	
7/2	9.0	18,460
7/3	8.9	
7/4	8.4	
7/5	9.2	
7/6	9.8	
7/7	10.0	
7/8	9.3	
7/9	9.2	
7/10	10.2	19,910
7/11	10.1	19,910
7/12	9.7	20,240
7/13	9.5	20,240
7/14	9.5	20,100
7/15	10.1	20,100
7/16	10.0	
7/17	10.7	19,910
7/18	10.5	20,280
7/19	9.9	
7/20	9.5	
7/21	9.5	20,370
7/22	9.9	
7/23	9.6	20,280
7/24	8.4	20,280
7/25	7.5	19,910
7/26	8.1	20,280
7/27	9.4	
7/28	10.2	
7/29	9.7	
7/30	9.2	19,180
7/31	10.2	18,460
8/1	10.8	
8/2	11.1	
8/3	11.4	20,280
8/4	10.8	20,280
8/5	10.0	20,280
8/6	10.4	20,280
8/7	9.7	19,910
8/8	9.9	19,500
8/9	10.9	
8/10	11.1	
Mean	9.7	19,929
Min	7.5	18,460
Max	11.4	20,370